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Research Article

Analysis of Water Quality at Way Belerang Simpur Hot Spring Tourist Site in Kecapi Village, Kalianda District, South Lampung Regency, Lampung Province

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Abstract

Way Belerang Simpur is a sulfur-containing hot spring that serves as a popular tourist destination for hot spring baths. This study aims to evaluate the water quality of the spring using physical, chemical, and biological parameters. Water samples were taken from three points: the source (Point 1), the bathing area (Point 2), and the downstream flow (Point 3). The parameters analyzed include temperature, pH, dissolved oxygen (DO), odor, hydrogen sulfide (H2S), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total coliform bacteria. Standard testing methods such as mercury thermometers, pH meters, spectrophotometry, and SNI protocols were used. Results show that temperature and odor meet national standards for safe water, but pH levels were highly acidic, exceeding acceptable limits for public bathing. DO levels were adequate to support aquatic life, while BOD, COD, and H2S were within acceptable limits. The biological analysis revealed very low levels of total coliform bacteria, making the water microbiologically safe. Overall, the water quality at Way Belerang Simpur is suitable in terms of contamination levels but presents risks due to its high temperature and low pH, especially for prolonged exposure.

Keywords: Dissolved oxygen; Hot Spring; pH; Total Coliform; Water Quality

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INTRODUCTION

Natural resources play a crucial role in human life. They not only have economic value but also carry social, cultural, and political significance [1], [2], [3]. Biological natural resources include flora, fauna, water, soil, and minerals [4], [5]. Water is a fundamental necessity for all living organisms, not only for humans but also for animals and plants [6], [7], [8].

Springs are categorized into several types, such as seepage springs, which emerge from slopes, and artesian springs, which flow from within the ground. Springs are further classified into large, small, and hot springs [9], [10], [11]. Hot springs are commonly found in active volcanic areas experiencing eruptions. They form due to two factors: active tectonic activity and volcanism. Volcanic hot springs are characterized by a constant temperature of 100°C, along with deposits of sinter, sulfate, sulfur, and others. Meanwhile, tectonic hot springs have lower temperatures (20-100°C) and lower mineral content [12], [13]. Hot springs, with temperatures exceeding 37°C or reaching boiling point, are rich in minerals such as calcium, lithium, and sulfur, among others.

According to Government Regulation No. 66 of 2014 on Environmental Health, a healthy environment is determined by Environmental Health Quality Standards and Health Requirements. Water used for sanitation, swimming pools, spas, and public baths must meet specific quality standards to ensure public health, covering physical, chemical, and biological parameters [14]. This study assesses water quality at the Way Belerang hot spring based on physical, chemical, and biological parameters, including temperature, odor, pH, sulfur as H2S, Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), and total coliform [15], [16], [17]. Water quality analysis takes into account various physical, chemical, and biological parameters influenced by environmental conditions and geothermal processes.

The temperature of springs originating from volcanic activity typically approaches boiling point, often reaching 100°C or higher [17]. Water temperature is generally affected by factors such as sunlight intensity, heat exchange between water and surrounding air, and altitude [18], [19]. In hot spring systems, pH ranges from 4 to 9, with surface water exhibiting a higher pH compared to deeper water. This pH value reflects the type of water in the geothermal system, which depends on the chemical content within it [20], [21]. The BOD value, measured in mg/L, represents the difference between initial and final dissolved oxygen levels (DO0 – DO5). DO can be measured using a DO meter or titration methods such as Winkler and iodometry [22].

COD measures the total amount of organic material, both biodegradable and non-biodegradable, while BOD only measures the biodegradable portion. The BOD/COD ratio can indicate the level of biodegradability. A BOD/COD ratio ≥ 0.8 signifies high pollution [23]. This ratio evaluates the potential for organic contamination, and biological factors such as coliform bacteria must also be considered. Coliform bacteria, including *Escherichia coli* and *Enterobacter aerogenes*, reside in the human digestive tract and indicate the presence of pathogenic bacteria [24], [25]. The fewer coliforms present, the better the water quality. These bacteria are rod-shaped, gram-negative, non-spore-forming, and capable of fermenting lactose with gas and acid production at 37°C within 48 hours [26].

Lampung Province is home to many tourist attractions, including natural sites. In Kecapi Village, Kalianda Subdistrict, South Lampung, there is a natural hot spring located at the foot of Mount Rajabasa. This hot spring, known as Way Belerang Simpur, has exceptionally high temperatures and a sulfuric odor [27]. Way Belerang Simpur is a natural hot sulfur spring, a phenomenon that originates deep within the Earth. Some parts of the spring are extremely hot, while others are mixed with cooler mountain water [28].

In the past three months, Way Belerang Simpur recorded 1,287 visitors in January, 1,225 visitors in February, and 865 visitors in March, totaling 3,377 visitors. The site is popular due to its believed health benefits, particularly for skin, attributed to its sulfur content. Bathing in the warm water is also believed to help maintain body stamina [28].

Way Belerang Simpur is a popular destination, attracting many visitors, both tourists and locals. However, the high number of visitors increases the risk of water pollution, which can affect the overall water quality. As the water quality at Way Belerang Simpur has not been thoroughly studied, this research aims to assess it through physical, chemical, and biological parameters. These include temperature, odor, pH, BOD, COD, DO, sulfur (H2S), and total coliform. The assessment will be compared to the standards set by Indonesian Government Regulation Number 82 of 2001 on Water Quality Management and Water Pollution Control, which classifies water quality for various uses.

The results of the study show that the water temperature at three sampling points ranges from 38°C to 55°C, with a typical sulfur odor detected at points 1 and 2, and normal odor at point 3. Chemically, the pH values (1.4–2.1) do not meet the water quality standards, but the DO levels (5.71–6.52 mg/L) exceed the minimum required standard of 4 mg/L. Additionally, BOD (≤3 mg/L), COD (≤18 mg/L), and sulfur content as H2S (≤0.001 mg/L) are within acceptable limits. Biologically, the total coliform levels in all three samples are below the threshold (<3), indicating that the water is suitable for public bathing.

Way Belerang Simpur is a popular tourist destination located at the foot of Mount Rajabasa, known for its hot springs with high temperatures and sulfur content, which are believed to offer health benefits, particularly for the skin. However, the high number of visitors raises concerns about potential water pollution. Previous research by Jamaluddin and Emi Prasetyawati Umar on hot springs in Southeast Sulawesi provided valuable insights into the physical and chemical properties of hot springs, such as pH, temperature, sulfur content, and salinity. However, their study did not address important biological factors like total coliform, which are crucial for determining the water's suitability for public use [29].

The purpose of this research is to assess the water quality based on physical parameters, such as temperature and odor, at Way Belerang Simpur hot spring. Additionally, the study aims to evaluate the water quality based on chemical parameters, including pH, BOD, COD, DO, and sulfur, as well as assess the biological parameters, particularly the presence of total coliform, to determine the overall suitability of the water for recreational use.

METHODS

The study was conducted at Way Belerang Simpur, a natural hot spring located in Desa Kecapi, Kecamatan Kalianda, Lampung Selatan, Indonesia. The area is situated between 104°15'–105°45' East Longitude and 5°15'–6° South Latitude, at the foot of Mount Rajabasa. The site is geographically bordered by Desa Tajimalela to the north, Mount Rajabasa to the south, Desa Pematang to the west, and Desa Babulang to the east. The hot spring, known for its sulfuric content and believed health benefits, has been a popular destination for both tourists and locals. However, the water quality has not yet been extensively studied, necessitating a thorough examination of the physical, chemical, and biological properties of the water.

Kecapi Vilage covers an area of 585 hectares, including residential areas, agricultural land, forests, and water bodies. The hot spring area itself spans 2 hectares. The elevation of the site ranges from 300 to 500 meters above sea level, with a predominantly flat to gently rolling terrain. The climate is characterized by an average annual rainfall of 1,500–3,000 mm, with temperatures ranging between 25°C and 31°C. The humidity is approximately 65%, and the soil is predominantly red podzolic, with a pH ranging from 5.5 to 7.

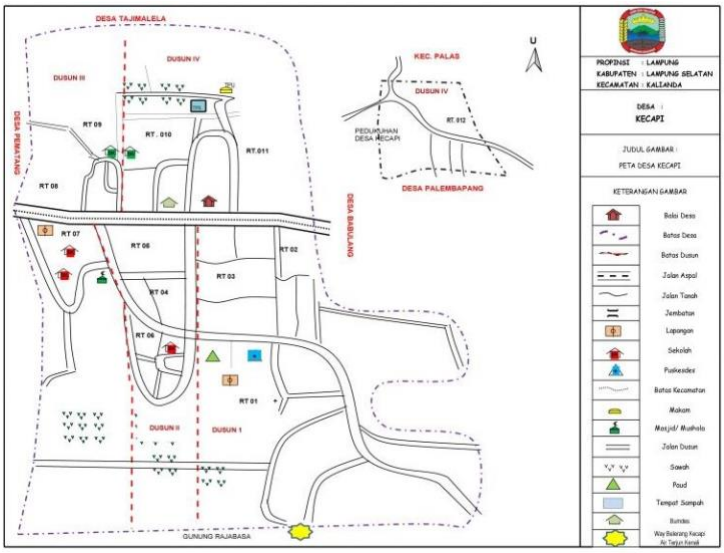

Figure 1. Map of Way Belerang Simpur

Sampling Procedures

Water sampling was conducted at three designated points around Way Belerang Simpur hot spring to ensure a comprehensive assessment of water quality. These points were strategically selected based on their proximity to tourist activity and potential environmental impact. The three sampling points were as follows:

1. **Point 1:** Located directly at the source of the hot spring, where the water emerges from the ground and is at its highest temperature.
2. **Point 2:** Located in the bathing area, where hot and cold water mix, downstream from the source, and where visitors typically bathe.

3. **Point 3:** Located at the downstream flow, where water flows away from the bathing area and continues toward lower regions.

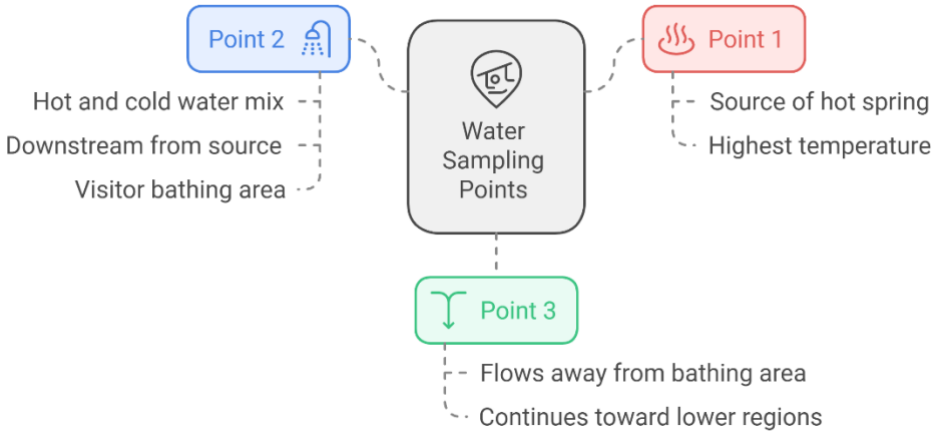

Figure 2. Progression of Water Sampling

Samples were collected in sterile glass containers and transported to the laboratory in coolers to maintain chemical stability. On-site measurements, including temperature, pH, and dissolved oxygen (DO), were taken using a multiparameter probe for real-time data collection. The sampling procedures adhered to standard methods recommended by the Indonesian Ministry of Health to ensure the accuracy and reliability of the data collected.

Physical, Chemical, and Biological Parameter Measurements

To evaluate the water quality at Way Belerang Simpur, the study focused on three main types of parameters: physical, chemical, and biological.

1. **Physical Parameters:**
   a. **Temperature:** The water temperature was measured in situ using a digital thermometer. Measurements were taken at all three sampling points to capture variations in water temperature due to natural cooling and mixing with other water sources.
   b. **Odor:** The sulfuric odor was assessed qualitatively at each sampling point. The characteristic sulfur smell was noted, especially at the source, which is closest to the volcanic activity of Mount Rajabasa.

2. **Chemical Parameters:**
   a. pH: Water samples were analyzed for pH using a calibrated pH meter. The expected pH range of geothermal hot springs is between 4 and 9, and deviations from these values were closely monitored.
   b. Dissolved Oxygen (DO): DO levels were measured in situ using a portable DO meter to assess the oxygenation of the water. Higher DO levels indicate better water quality.

c. **Biochemical Oxygen Demand (BOD):** BOD tests were conducted to measure the amount of oxygen consumed by microorganisms during the decomposition of organic matter.
d. **Chemical Oxygen Demand (COD):** COD was analyzed to determine the amount of oxygen required to oxidize both organic and inorganic materials in the water. This test complements the BOD measurement and provides a broader understanding of the water's organic load.
e. **Sulfur as H2S:** The concentration of sulfur as hydrogen sulfide (H2S) was determined using iodometric titration to understand the impact of sulfur emissions from the volcanic source.

3. **Biological Parameters:**
   a. **Total Coliform:** Coliform bacteria levels were measured to assess the biological contamination of the water. This was done using the membrane filtration method, following the Standard Methods for the Examination of Water and Wastewater. The presence of coliforms, particularly Escherichia coli, serves as an indicator of potential fecal contamination.

Methods Used for Data Collection and Analysis

To ensure reliable results, this study utilized in situ measurements, laboratory tests, and statistical analysis. Physical parameters such as temperature, dissolved oxygen (DO), and pH were measured on-site using portable instruments, providing real-time data on water conditions. Water samples were then transported to a certified laboratory for detailed chemical and biological analyses, including tests for BOD, COD, sulfur (H2S), and coliform bacteria using titration and filtration methods.

For data analysis, water quality results were compared with Indonesian Government Regulation Number 82 of 2001 and the Ministry of Health Regulation Number 32 of 2017. The **Storet method** was applied to assess deviations from these standards, allowing a quantitative evaluation of the water's suitability for public use. Quality control measures included instrument calibration, use of standard solutions, and collection of duplicate samples to ensure consistency. The laboratory adhered to ISO 17025 standards, ensuring accuracy and reliability throughout the testing process.

RESULT AND DISCUSSIONS

Water Quality Assessment

The water quality at Way Belerang Simpur hot spring was assessed through the analysis of physical, chemical, and biological parameters. Samples were collected from three distinct locations: the source of the hot spring (Point 1), the area where hot and cold waters mix (Point 2), and the bathing area (Point 3). The results were compared to the Indonesian Government Regulation No. 82 of 2001 and Ministry of Health Regulation No. 32 of 2017 for public bathing water standards.

Table 1. Variations in Physical, Chemical, and Biological Parameters at Way Belerang Simpur

Parameter	Method	Point 1	Point 2	Point 3	Standard
Temperature (°C)	Mercury Thermometer	55°C	44°C	38°C	15-35°C
pH	pH Meter	1.4	2.0	2.1	6-9
Dissolved Oxygen (DO) (mg/L)	SNI 06-6989.14-2004	5.71	6.11	6.52	≥ 4
Odor	Sensory (IK 26/AP/BRS-BL)	Normal (sulfuric)	Normal (sulfuric)	Normal	No unpleasant smell
Hydrogen Sulfide (H2S) (mg/L)	Methylene Blue Method (IK 04/Lc/BRSBL)	0.001	<0.001	0.001	0.002
Biochemical Oxygen Demand (BOD) (mg/L)	SNI 6989.72:2009	3	< 2	< 2	3
Chemical Oxygen Demand (COD) (mg/L)	Spectrophotometry (IK 02/LC/BRSBL)	18	8	2	25
Total Coliform (CFU/100 mL)	SNI 06-4158-1996	< 3	< 3	< 3	5000

Physical Parameters

The water temperature varied between 38°C and 55°C across the three points. Point 1, located at the source of the hot spring, recorded the highest temperature at 55°C. Point 2, at the bathing area, registered a lower temperature of 44°C, and Point 3, the downstream flow, recorded 38°C. According to national standards, the acceptable temperature range for public bathing is between 15°C and 35°C. Therefore, temperatures at Points 1 and 2 exceeded the acceptable limits, posing potential health risks such as skin irritation or burns during prolonged exposure. The values were as follows:

Table 2. Physical Parameters at Way Belerang Simpur

Parameter	Unit	Standard	Point 1	Point 2	Point 3
Temperature	°C	15-35	55°C	44°C	38°C
Odor	-	No unpleasant smell	Normal (Sulfuric)	Normal (Sulfuric)	Normal
UV Index	-	< 3	Not measured	Not measured	Not measured
Clarity	Meter	1.6	Not measured	Not measured	Not measured

The results show that temperatures at Points 1 and 2 are significantly higher than recommended for safe prolonged water contact, indicating potential risks for visitors.

Chemical Parameters

The pH levels at the three points indicated that the water was highly acidic, with Point 1 recording 1.4, Point 2 at 2.0, and Point 3 at 2.1. These values are well below the acceptable pH range of 6-9 for public bathing water, making the water unsuitable for prolonged human contact, as it can cause skin and eye irritation. The Dissolved Oxygen (DO) levels at all three points exceeded the minimum required value of 4 mg/L. Point 1 recorded 5.71 mg/L, Point 2 had 6.11 mg/L, and Point 3 had the highest value at 6.52 mg/L. This indicates that the water is well-oxygenated, but the high acidity could limit the types of organisms that can survive in such an environment.

Table 3. Chemical Parameters at Way Belerang Simpur

Parameter	Unit	Standard	Point 1	Point 2	Point 3
pH	-	6-9	1.4	2.0	2.1
Dissolved Oxygen (DO)	mg/L	≥ 4	5.71	6.11	6.52
Hydrogen Sulfide (H2S)	mg/L	≤ 0.002	0.001	< 0.001	0.001
Chemical Oxygen Demand (COD)	mg/L	≤ 25	18	8	2
Biochemical Oxygen Demand (BOD)	mg/L	≤ 3	3	< 2	< 2

The results indicate that while the Dissolved Oxygen (DO), COD, and BOD levels are within acceptable ranges, the highly acidic pH values make the water unsafe for bathing over long periods. Additionally, the presence of H2S remains below regulatory limits.

Biological Parameters

Total coliform bacteria, an indicator of fecal contamination, were measured at less than 3 CFU/100 mL at all three points. This is well below the regulatory limit of 5000 CFU/100 mL, indicating that the water is microbiologically safe for public use.

Table 4. Biological Parameters at Way Belerang Simpur

Parameter	Unit	Standard	Point 1	Point 2	Point 3
Total Coliform	CFU/100 mL	≤ 5000	< 3	< 3	< 3

Water Quality Assessment Using the STORET Method

To provide a comprehensive assessment of the water quality, the **STORET method** was applied. This method assigns penalty points for deviations from established water quality standards, allowing for a quantitative assessment of water quality. According to the STORET classification system, Way Belerang Simpur's water falls into the "moderately polluted" category due to its low pH and high temperature. Despite other parameters such as DO, BOD, COD, and coliform levels being within acceptable limits, the deviations in temperature and pH significantly impact the water’s overall quality status.

Table 5. STORET Method Analysis for Water Quality at Way Belerang Simpur

Parameter	Standard	Point 1	Point 2	Point 3	Score	Status
Temperature	15-35°C	55°C	44°C	38°C	-10	Moderately Polluted
pH	6-9	1.4	2.0	2.1	-10	Moderately Polluted
DO	≥ 4 mg/L	5.71 mg/L	6.11 mg/L	6.52 mg/L	0	Good
BOD	≤ 3 mg/L	3 mg/L	< 2 mg/L	< 2 mg/L	0	Good
COD	≤ 25 mg/L	18 mg/L	8 mg/L	2 mg/L	0	Good
H2S	≤ 0.002 mg/L	0.001 mg/L	< 0.001 mg/L	0.001 mg/L	0	Good
Total Coliform	≤ 5000 CFU/100 mL	< 3 CFU/100 mL	< 3 CFU/100 mL	< 3 CFU/100 mL	0	Good

The STORET analysis reveals that while most chemical and biological parameters meet national standards, the low pH and high temperatures contribute significantly to the "moderately polluted" classification. These deviations highlight the geothermal origin of the water, which naturally causes elevated temperatures and acidity, yet these conditions can still pose risks for prolonged recreational use.

Implications for Public Health and Environmental Management

The results of this study indicate that Way Belerang Simpur hot spring presents unique challenges due to its geothermal properties. The high temperature and acidic nature of the water pose potential health risks for visitors, particularly those engaging in prolonged bathing or immersion. Public health warnings should be clearly posted to inform visitors of the risks associated with extended exposure to the water, especially at Points 1 and 2 where temperatures and acidity are highest.

From an environmental management perspective, the water quality should continue to be monitored, particularly in relation to its acidity, as changes in volcanic activity could lead to further fluctuations in pH and temperature. Additionally, maintaining the cleanliness of the surrounding area is crucial to prevent any potential contamination that could negatively impact water quality over time.

CONCLUSION

In conclusion, the water quality at Way Belerang Simpur, based on physical, chemical, and biological parameters, reveals that while certain aspects are within acceptable limits, others pose potential risks. The elevated water temperatures, particularly at the source (55°C), and the highly acidic pH levels (ranging from 1.4 to 2.1) exceed recommended standards for recreational use, making the water unsuitable for prolonged exposure. However, the levels of dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), hydrogen sulfide (H2S), and total coliform bacteria are within regulatory limits, indicating that the water is largely free from harmful organic pollutants and microbiological contamination. Despite these positive

aspects, the overall suitability of the water for public use is compromised by the high temperature and acidity. Therefore, further monitoring and caution are advised to ensure the health and safety of visitors.

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CONFLICT OF INTEREST

"The authors declare no conflict of interest."

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